

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of:
FROSSEN, JUERGEN

Serial No.: 10/593,246

Confirmation No.: 9935

Filed: July 17, 2007

For: HIGH CURRENT DENSITY
PARTICLE BEAM SYSTEM

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Group Art Unit: 2878


Examiner:

Int'l App. No. PCT/EP05/001637

Int'l App. Filing Date: 2/17/2005

Commissioner for Patents
P.O. Box 1450
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Dear Sir:

CERTIFICATE OF TRANSMISSION	
I hereby certify that this correspondence is being electronically transmitted to the U.S. Patent and Trademark Office via EFS-Web to the Commissioner for Patents, on the date shown below.	
2/13/08	
Date	Keith M. Tackett, Reg. No. 32,008

REQUEST FOR REPUBLICATION UNDER 37 C.F.R. 1.221(b)

Applicant respectfully requests Republication of this application because the application was published as US2007/0284536 A1 with an editorial error made by the United States Patent and Trademark Office. Applicant submits that the description of the system as shown in Fig. 2 on page 10, line 23 of the specification (paragraph [0061] in publication) was published with an error made by the USPTO. A marked page showing the error in the publication and a marked page showing application as filed are attached to this request.

Respectfully submitted,



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As already described with respect to fig. 1b, without being limited thereto, a beam path without a crossover can be considered advantageous. Since each of the electron beam bundles 21a and 21b is optimized with regard to the beam current, the electron current density on the specimen can be increased n-times by providing n electron beam bundles.

Thereby, aperture arrangement 26 is arranged close to the emitter so that a separation into independent electron beams takes place as soon as possible within the column. Within the embodiment shown in fig. 2, the aperture arrangement and thereby the beam bundles are arranged symmetrically with respect to optical axis 1. Thus, the optical imaging characteristic of the electron beam column is similar for electron beam 21a and 21b.

However, generally, it has to be considered disadvantageous to provide an electron beam path with electron beams traveling significantly off-axis. Yet, the aperture arrangement 26 as shown in fig. 2 has off-axial aperture locations. Thereby, spherical aberrations will be increased. Generally, the diameter of the electron probe can be described as:

$$D_{\text{probe}} = (D_{\text{spherical}}^2 + D_{\text{chromatic}}^2 + D_{\text{interaction}}^2)^{1/2}$$

The spherical aberration depends on the third order of aperture angle α .

$$D_{\text{spherical}} = C_s \alpha^3$$

Thus, providing off-axis beam bundles is contradictory to the general teaching of minimizing possible aberrations. However, the system as shown in fig. 2 can be better described by:



$$D_{\text{spherical enlargement}} = 3C_s \alpha_B \alpha^2$$

whereby α is the angle between the center of the aperture and the optical axis. Thus, spherical aberrations increase merely with the second order of the angle between aperture and optical axis.

Especially for applications with high current density, which are interaction dominated anyway, spherical aberrations can be neglected up to a certain degree. Nevertheless, the distance $D/2$ of the electron bundle from optical axis 1 should be as small as possible without introducing any

either be electrostatic, magnetic or compound electrostatic-magnetic. Thereby, also high precision lenses as described in European patent application No. 03025353.8 by Frosien may be used as one option.

[0058] As already described with respect to FIG. 1b, without being limited thereto, a beam path without a cross-over can be considered advantageous. Since each of the electron beam bundles 21a and 21b is optimized with regard to the beam current, the electron current density on the specimen can be increased n-times by providing n electron beam bundles.

[0059] Thereby, aperture arrangement 26 is arranged close to the emitter so that a separation into independent electron beams takes place as soon as possible within the column. Within the embodiment shown in FIG. 2, the aperture arrangement and thereby the beam bundles are arranged symmetrically with respect to optical axis 1. Thus, the optical imaging characteristic of the electron beam column is similar for electron beam 21a and 21b.

[0060] However, generally, it has to be considered disadvantageous to provide an electron beam path with electron beams traveling significantly off-axis. Yet, the aperture arrangement 26 as shown in FIG. 2 has off-axial aperture locations. Thereby, spherical aberrations will be increased. Generally, the diameter of the electron probe can be described as:

$$D_{\text{probe}} = (D_{\text{aperture}}^2 + D_{\text{chromatic}}^2 + D_{\text{intercolumn}}^2)^{1/2}$$

The spherical aberration depends on the third order of aperture angle α .

$$D_{\text{spherical}} \propto \alpha^3$$

[0061] Thus, providing off-axis beam bundles is contradictory to the general teaching of minimizing possible aberrations. However, the system as shown in FIG. 2 can be better described by:

$$D_{\text{spherical aberration}} = 3C_s \alpha^3 \quad \text{See p. 10}$$

[0062] whereby α is the angle between the center of the aperture and the optical axis. Thus, spherical aberrations increase merely with the second order of the angle between aperture and optical axis.

[0063] Especially for applications with high current density, which are interaction dominated anyway, spherical aberrations can be neglected up to a certain degree. Nevertheless, the distance D_2 of the electron bundle from optical axis 1 should be as small as possible without introducing any interaction between the independent electron beams. Typical design criteria could be that the aperture openings and the distances between the aperture are in the same order of magnitude.

[0064] Embodiments of aperture arrangements will now be described with respect to FIGS. 3a to 3d. Within FIG. 3a, two apertures 36a are arranged with the 2-fold symmetry around the optical axis. Thereby, the electron bundles have a distance D_1 . The sizes of the apertures are indicated by reference sign S_1 . The apertures are arranged on a virtual circle around optical axis 1. Within FIG. 3b, three apertures are arranged in 3-fold symmetry. By increasing the number of apertures, the distance between the electron beams is decreased unless the size of the apertures is reduced.

[0065] Thus, for the aperture arrangement 26b within FIG. 3b, the distance D_2 between the electron bundles is realized by having an aperture size S_2 , which is smaller than aperture size S_1 . The apertures 36 of aperture arrangement 26c shown in FIG. 3c are further reduced in size in order to realize distance D_3 between the electron beams. The four apertures in FIG. 3c are arranged in 4-fold symmetry around optical axis 1.

[0066] A further embodiment that differs from the above-mentioned embodiments is shown in FIG. 3d. Thereby, a ring is segmented to form apertures 36. Thereby, aperture arrangement 26d includes eight apertures with 8-fold symmetry around optical axis 1.

[0067] The above-described embodiments of FIGS. 3a to 3d are examples for aperture arrangements with different distances D_1 to D_4 , whereby each distance is sufficiently large in order not to have any inter-bundle interaction. Nevertheless, aperture arrangements with different numbers of apertures can be realized. Further, the symmetrical formation around optical axis 1 is a typical arrangement having some advantages, which will be described in the following. However, the present invention is not limited thereto.

[0068] The symmetrical formation of the apertures can be considered advantageous with regard to the emission characteristics of the gun. Typical emission angles, e.g. from TFE, have a value of $\alpha_{\text{emission}} = 10^\circ$ rad, which shows homogeneous current density. Accordingly, the apertures should be arranged within this emission angle to be illuminated homogeneously. This results in homogeneous current density of all electron beam bundles. Therefore, the above-mentioned symmetry may be considered advantageous in order to have the same illumination for all apertures.

[0069] Generally, without reference to any of the specific embodiments, the distance of the apertures from the optical axis should be as small as possible to keep the spherical aberration contribution as small as possible. However, the distance has to be made large enough that different electron bundles do not interact with each other.

[0070] Other embodiments according to the present invention are shown in FIGS. 8a to 8d. Therein, 4-fold symmetric aperture arrangements 86a to 86d are shown. This rotational symmetry by 90° has the advantage, that the resulting spherical aberrations can be corrected with an octupole element that may be present in typical charged particle beam inspection or testing devices. However, also an aperture arrangement with a 2-fold symmetry (as described in FIG. 3a) might be used and the aberrations introduced may also be easily corrected.

[0071] FIG. 8a shows an aperture arrangement with four apertures 36a to 36d. The apertures have rectangular shape. Typically the longer dimension of the aperture is radially orientated. Thereby, the introduced spherical aberrations have advantageously correctable spherical aberrations.

[0072] A further embodiment (see FIG. 8a) also has 4 apertures. However, the apertures do extend further towards an optical axis, which would be located essentially in the middle of the aperture arrangement 86b.

[0073] Within FIG. 8c, the apertures are further extended towards the center. Thereby a cross-shaped aperture is realized. Such an aperture arrangement does no longer form